

High speed rectifiers for coupling efficiency enhancement in THz rectenna scavengers

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Rectennas have been proven in harvesting artificial energy sources in the radio/microwave regime of the energy spectrum making them successful in wireless applications. Their potential to operate at higher IR/THz frequencies has been hindered by the lack of a diode nanostructure that can work efficiently when coupled to antennas. The rise of nanotechnology – bringing the patterning capability down to the nano scale – makes it possible therefore to move these devices towards the THz regime. This work involves experimental and theoretical work which focuses on optimizing the diode structures giving a further understanding of their suitability of being integrated into rectenna scavengers. Metal-insulator-(insulator)-metal structures are the only simple solid-state rectifiers which are capable of operating at THz frequencies due to the femtosecond-speed quantum tunneling mechanisms governing the charge transport when the dielectrics are sufficiently thin. These devices have been fabricated and characterised, studying the thermal emission processes hindering the speed. The aim is to optimise the fabrication towards a dominant mechanism of polarity-dependent tunneling so as to realise the desired high speed rectification. The operation of these devices at high THz frequencies requires the minimization of the diode active area. A significant loss in the THz-to-DC conversion efficiency occurs in the diode coupling efficiency. Reported THz rectifiers have shown a trade-off between sufficient rectification and lowering the impedance making the diode-antenna matching very challenging with the nanostructure needed for THz energy scavenging. The rectifying characteristics are tuned towards tunneling domination, lower impedance, sufficient asymmetry and non-linearity, and reduction in the turn-on voltage. Different tunneling mechanisms are discussed giving further understanding of the rectifying performance of ultra-thin dielectrics. This enhancement demonstrates the feasibility of rectenna technology at optical frequencies and opens the road towards energy harvesting ranging from the surface of the earth, infrared emissions to space and towards solar energy (100's THz).